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A survey of achieved levels of airborne sound insulation in broadcasting studio centres

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A SURVEY OF ACHIEVED LEVELS OF AIRBORNE SOUND INSULATION IN BROADCASTING STUDIO CENTRES

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Summary

A survey has been carried out on results from field measurements over the past fifteen years of the sound insulation of partitions in the technical areas of studio centres. The conduct of that survey is outlined and some examples of the acoustic performance of partitions are given.

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Section Page

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1. INTRODUCTION

Over a period of many years the BBC has been designing, building and evaluating studios, control rooms and other technical areas where one of the prime considerations has been the acoustic performance of the rooms. Field measurements have been made on a routine basis, both during and at the end of constructional work, to establish the reverberation time and decay shapes for each room, the background noise level in each room under various operating conditions, and the sound insulation between rooms. Results of such tests are then compared against the appropriate criteria and the success or otherwise of the original design can be thus determined; they also serve as a check on the standards of construction.

In the course of such evaluations many results have been collected in the BBC which relate the achieved sound level differences between rooms, to the constructions which separate them. In general, detailed results are available within the BBC from tests carried out over the last fifteen years, but earlier results fail to record sufficiently detailed information on the wall construction to make the sound insulation data meaningful beyond the context in which it was orginally recorded.

Sufficient data is available however from the more recent tests to make a study of partition performance worthwhile. This Report describes the study and outlines some of the results which have been achieved. A companion document[1] presents the full results of the survey in a form suitable to the acoustic design engineer.

2. METHOD OF MEASUREMENT

Within the BBC the sound insulation performance of a partition is assessed by measuring the sound level difference across the partition. The technique is to excite one side of the partition with a source of sound and to measure the resultant sound pressure level on both sides of it. The difference between these two values is the sound level difference of the partition.

The source of sound for this measurement has historically been a frequency-modulated tone* swept manually across the audio band. The use of a narrow-band fixed-level signal such as this gives a higher average undistorted sound level from a conventional loudspeaker than would be possible using random noise, whilst at the same time avoiding the problem of exciting single eigentones (room resonance modes) which would result if unmodulated swept-frequency tones were used. The 'warble' tone, as it is known, is radiated into the 'source' room by a loudspeaker, so positioned that the partition is, as nearly as possible, entirely in the reverberant sound field. This usually means that the loudspeaker is made to face the surface opposite the partition (wall) under test or one of the opposite corners so that only reflected sound energy is incident on the partition under test (see Fig. 1).

The instrumentation for measuring the sound level in both the 'source' and the 'receive' areas has changed over the years. Originally, precision sound level meters conforming to IEC Recommendation 179[2] were used and spot measurements were made at ISO standard 1/3 octave frequency intervals with the sound level meter switched to RMS FAST. Normally, measurements would have been made at a minimum of five microphone positions on both sides of the partition, a very laborious and

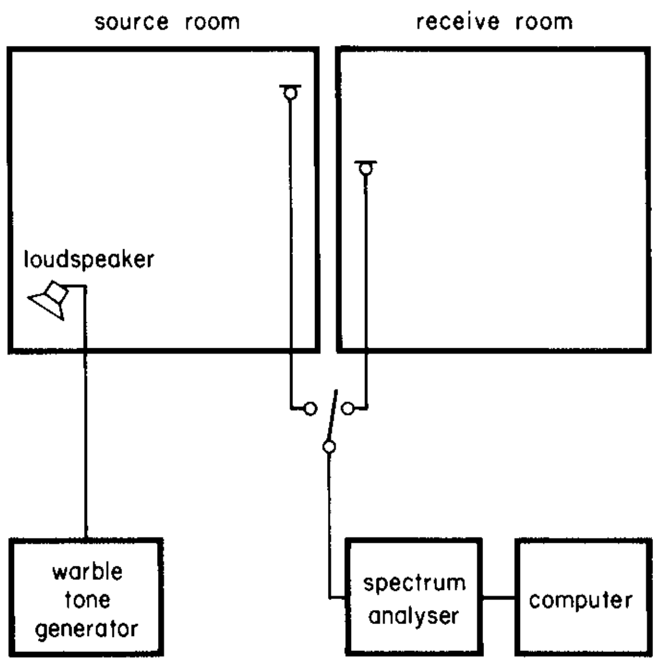


Fig. 1 - Conventional technique for measuring sound insulation.

*The frequency deviation is 10% at a rate of 5 Hz.

time consuming practice. More recently, in order to reduce the measurement times and return the studio more quickly to its normal activities, a real-time audio spectrum analyser, still conforming to IEC 179, has been used. This allows the whole spectrum to be captured in one sweep of the audio source.

The microphone positions are selected to give as true an indication as possible of the incident sound pressure level on the source side, whilst measuring the breakthrough into the receive room throughout the volume of that room, particularly for small rooms. Under normal circumstances the microphone is never positioned closer than one metre to a reflecting surface and it is set to varying heights during the tests.

The above measurement technique is used in the normal course of events, and generates the average steady state, reverberant field sound level difference for the partition under test. The only occasions where a radically different approach is needed is where the average sound level difference is expected to exceed about 70 dB. Previously, under such circumstances, a sufficiently high source level was used to ensure that the breakthrough into the receive room exceeded the background noise level in that room. This required, as source, the use of a theatrical maroon consisting of an 8 gram charge of electrically detonated explosive. These had been measured, using conventional acoustic equipment, to be capable of generating a sound pressure level of between 123 dB and 135 dB in 1/3 octave bands from 63 Hz to 58 Hz. However, the risk of overloading conventional equipment was always considered to be a possibility and the advent of new Fast Fourier Transform (FFT) based equipment capable of much higher analysis speeds has enabled more accurate measurements of the source impulse to be obtained. Free field measurements[3] of the temporal and spectral content of such an impulse are shown in Fig. 2. The peak unweighted sound pressure level is approximately 160 dB re 20 μPa at 6 m, whilst the sound level in the 125 Hz band is 148 dB re 20 μPa. The fact that such levels had not caused serious errors in earlier insulation measurements and results that were obviously unbelievable is, in itself, somewhat suprising. However the likelihood of errors is now considered to be sufficiently great for all such test results to be excluded from this survey.

An alternative method of measuring high levels of sound insulation was therefore needed and has recently been adopted. This was a source of cyclically repetitive pseudo-random noise (instead of warble tone) and synchronous averaging in the time domain on a Fast Fourier Transform Analyser to improve the signal-to-noise ratio in the receive room[3]. Thus, in theory, any uncorrelated acoustic or electrical source of noise in the measurement chain will integrate to zero, with the signal-to-noise ratio improving by 3 dB for each doubling of the measurement period. Though time consuming, this technique has been found to give at least 30 dB improvement in signal-to-noise ratio and nine of the better partitions, that had previously been tested with maroons, have been retested using this technique. These remeasured results have been included in the survey.

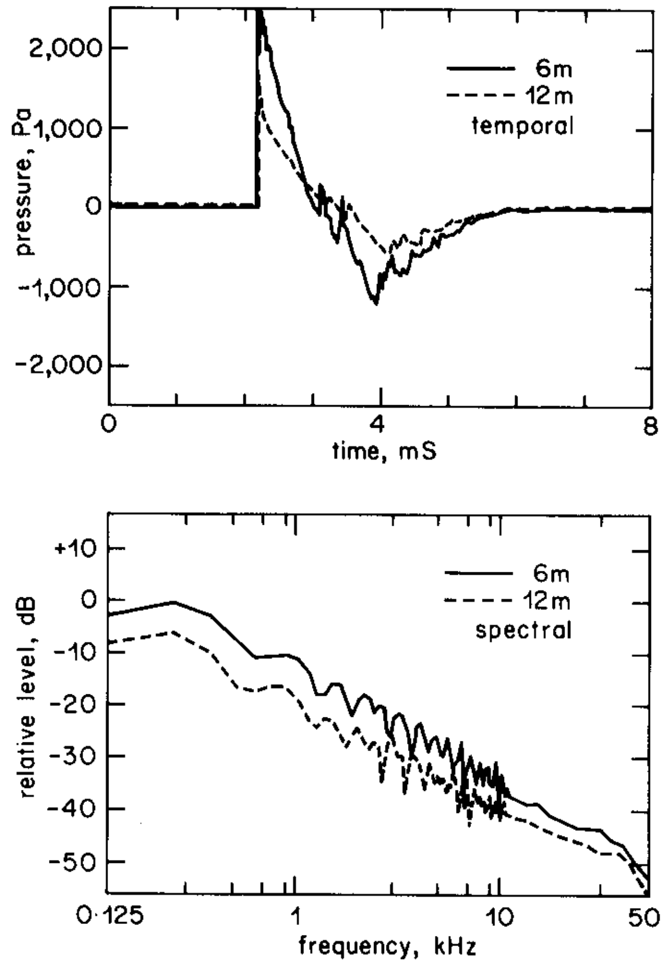


Fig.2 - Temporal and spectral analyses of the impulse of a theatrical maroon measured at distances of 6 mm and 12 mm.

3. ADDITIONAL DATA

Data on the airborne sound insulation of partitions suitable for studios is relatively hard to find. Considerable work has been carried out by other organisations on the acoustic performance of partitions between dwellings[4,5,6]. In addition generalised data can also be found in the literature[7,8,9]. Such sources of information, however, are restricted in the sense that they only deal with relatively low

performance partitions, say with an average insulation of less than 55 dB. In contrast, Gilford[10] illustrates constructions capable of average performances up to 70 dB but without giving many alternatives from which the designer can choose. Bearing in mind that the studio designer is often required to achieve this level of performance or better[11], the lack of published data can be a considerable problem.

The other variable in the presentation of airborne sound insulation data is the form in which the data is given. Normally a measurement would be made of the sound level difference in a way not too dissimilar from that outlined above. This would then be converted, particularly in the case of transmission suite measurements, to a sound reduction index according to the equation:

sound reduction index $= D + 10\log_{10}(A/S\alpha)$

where D is the difference between source and receive room sound pressure levels,

A is the area of the partition,

S is the surface area of the receive room,

and α is the average absorption coefficient for the receive room.

Alternatively one of two index normalising equations can be used[12] according to whether the chosen reference is an absorption of 10 sq. metre units or a receive room reverberation time of 0.5s, respectively.

Normalised sound level reduction

$$= D + 10\log_{10}(10/S\alpha)$$

or

$$= D + 10\log_{10}(t/0.5)$$

where t is the measured receive room reverberation time.

All three of the above indices allow the designer/consultant to compare the results for a partition in one set of circumstances with those of the same or alternative type of partition in a different set of circumstances. In this particular Report, however, the field measurements quoted are the sound level difference values as they were measured. They are therefore directly indicative of the subjective impression given by the partition. The only occasion on which this would not be true would be if the receive room was not in its finished acoustic state (say, no acoustic absorption was present) at the time of the measurement: such test results have not been included here.

4. EXAMPLES OF SURVEY RESULTS

Inevitably when a large organisation is erecting new, or modifying existing buildings over a number of years, a large number of different forms of wall construction are used. The full survey has indeed found such a range of partitions and these are covered in detail in the companion document[1]. For the purposes of this Report just a few examples are given.

4.1 Double Camden Partitions

When converting existing buildings into technical areas such as studios, one of the problems often encountered is that of the structure being able to take only limited floor loadings. To help in such circumstances the BBC has devised its own lightweight but lossy partition, which has become known as a Camden partition (because it was first used in the BBC's Camden Theatre, London). This consists of a 75 mm by 50 mm wooden stud frame, onto both sides of which is pinned first a layer of 12.5 mm softboard and then a layer of 12.5 mm plasterboard.

The construction is shown in its double form in Fig. 3. In this case the two exposed faces would receive a finishing skim coat of plaster. Such a partition would commonly be used between a talks studio and its control room in which circumstances there would be a triple glazed observation window and two communicating doors separated by a common sound lobby.

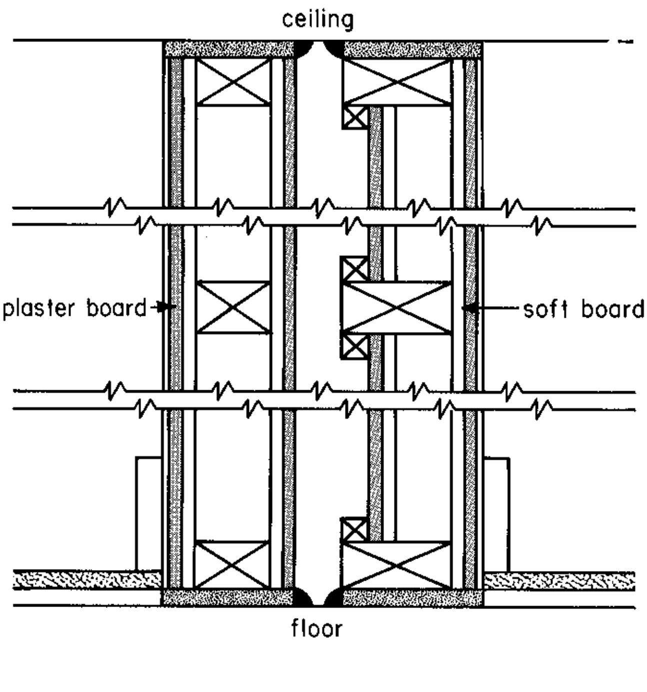
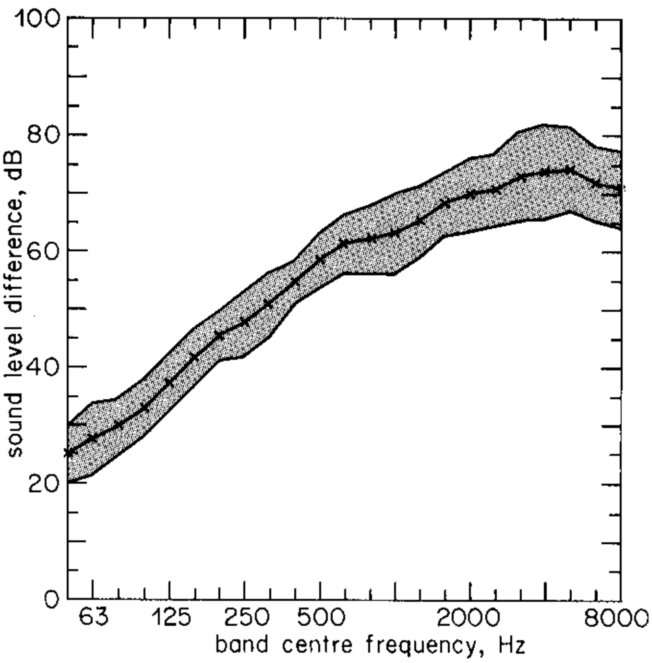


Fig.3 - Block diagram of a double Camden partition.

The survey included twenty eight samples of such a partition and the average sound level difference versus frequency characteristic for these is shown in Fig. 4. The plot shows the average curves plus and minus one standard deviation over the range 50 Hz to 8 kHz. As might be expected from a lightweight partition, the low frequency performance is somewhat limited, being only 25 dB at 50 Hz but at mid and high frequencies the insulation improves well to 63 dB at 1 kHz and 71 dB at 8 kHz. The plateau or even falling slope of the curve at high frequencies is indicative of the presence of flanking paths, i.e. sound leakage adjacent to the partition proper. This is almost inevitable in a partition pierced by doors, windows and cable ducts, despite the normal great care taken to prevent such sound leakage[13].

The numerical values given at the bottom of Fig. 4 are the mean insulation over the range 100 Hz to 2.5 kHz and the average of the individual standard deviations over the same range. These values allow a quick comparison of the results for one partition against those for another. In this particular case the mean insulation is 55.2 ± 5.8 dB.



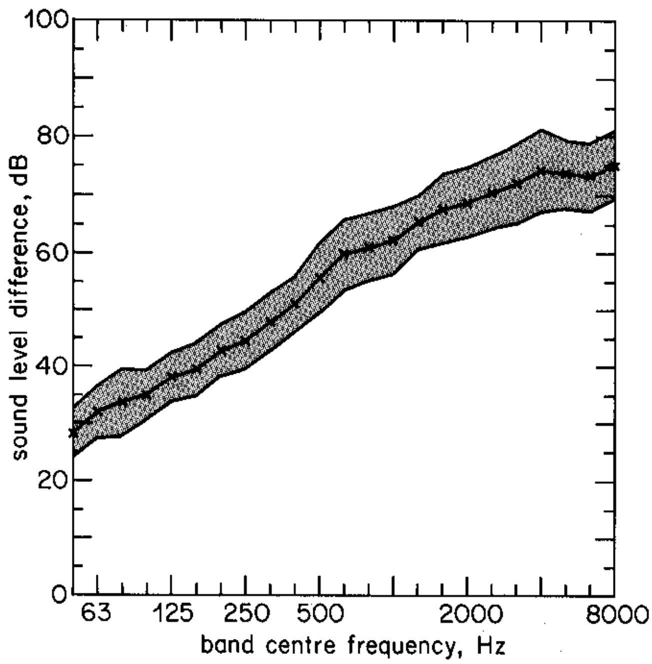
mean insulation 55·2dB standard deviation 5·8dB

Fig.4 - Sound insulation of double Camden partitions (with triple glazed windows and doors via a lobby).

4.2 Double 112 mm Brick Partition

Another commonly used partition is a double 112 mm brick partition with a 50 mm cavity. The exposed faces of the brick walls would generally be finished with plaster. As in the case of the double Camden partition, these are pierced by triple glazed windows and doors with an intermediate sound lobby. The results for thirty-seven such partitions are shown in Fig. 5.

Comparison with Fig. 4 shows that whilst the low frequency performance of the cavity brick partition is marginally improved due to its increased mass, the average performance 54.0 ± 5.5 dB is, within experimental error, the same as for a double Camden, a somewhat suprising result. However further analysis of the data[1] shows that two forms of constructional detail are encompassed within this group of partitions, namely those with solid wall ties and those with flexible wall ties within the two brick leaves. Separating the two groups yields average performance figures of 50.7 ± 3.8 dB for partitions with wire or strip wall ties and 56.3 ± 4.7 dB for partitions with flexible wall ties. Obviously if building regulations permit, it is better acoustically to use the flexible wall ties. Further improvements are possible by eliminating the connecting doors and windows. For a double 112 mm brick partition this increases the performance to 59.1 ± 7.5 dB. Beyond this, consideration has to be given to adding a third leaf.



mean insulation 54·0dB standard deviation 5·5dB

Fig.5 - Sound insulation of double 112 mm brick partitions with 50 mm cavities (with triple glazed windows and doors via a lobby).

4.3 Triple 150 mm Masonry Partition

One form of a triple leaf partition, is that using three 150 mm thick leaves with 50 mm cavities, the outer leaves being of blockwork whilst the centre leaf is of concrete (a load bearing wall).

In addition the outer leaves are floated on separate floor rafts in the two adjoining rooms. The floor rafts are of lightweight concrete screed, 'floating' on a blanket of mineral wool.

Two groups of such partitions have been found. The first, between studios and their own control rooms, includes triple glazed windows and double doors via sound lobbies. Fig. 6 shows the results for three such partitions, having an average performance of 62.1 ± 2.5 dB. The second group between studios and control rooms other than their own, does not include windows or doors. In this case, as shown in Fig. 7, the average of two partitions gives 84.4 ± 3.3 dB of insulation. Clearly the provision of observation windows and doors is more significant in determining the performance and average slope (8.1 dB/octave) for the partitions in the first group than are the other details of the partitions. Removing these practical limitations increases the average slope to 14.6 dB/octave, close to theoretical limit of 15 dB/octave. On-site supervision in this latter case must have been particularly good.

It is interesting to observe that the plot in Fig. 7 stops at 800 Hz. These tests were made with swept warble tone and a real-time spectrum analyser and clearly the experimenters were running into signal-to-noise ratio problems above 800 Hz, hence the lack of data above that frequency. However, this limit has been reached at a relatively low frequency for a comparatively modest structure, certainly in terms of its surface mass of 680 kg/m. Such a surface mass is equivalent to single leaf of brickwork 300 mm thick which theoretically would give only about 52 dB sound insulation. The structural breaks and attention to detail in this case are seen to be worth about 32 dB in terms of average sound insulation performance.

4.4 Partitions with Insulation above 80 dB

Although the last Section illustrated one form of partition giving 84 dB average insulation, partitions with average insulation above 80 dB are extremely rare and seldom, if ever, of the same construction. For completeness, however, it is worth recording those examples found in the survey. Five samples, other than the two mentioned above, were found and the results for them are shown in Fig. 8. Obviously it is not appropriate to present the average and standard deviation curves and so the individual sound level difference results are plotted.

Partition 1, with an average insulation of 95.3 dB, consists of two adjacent 'box within box' studio structures independently floated off separate foundations using neoprene antivibration pads with a third, spine wall between the floated structures. The floated walls are 228 mm brick and the spine wall is 456 mm brick. The two cavities are 1.5 m (used as a chair store) and 228 mm wide.

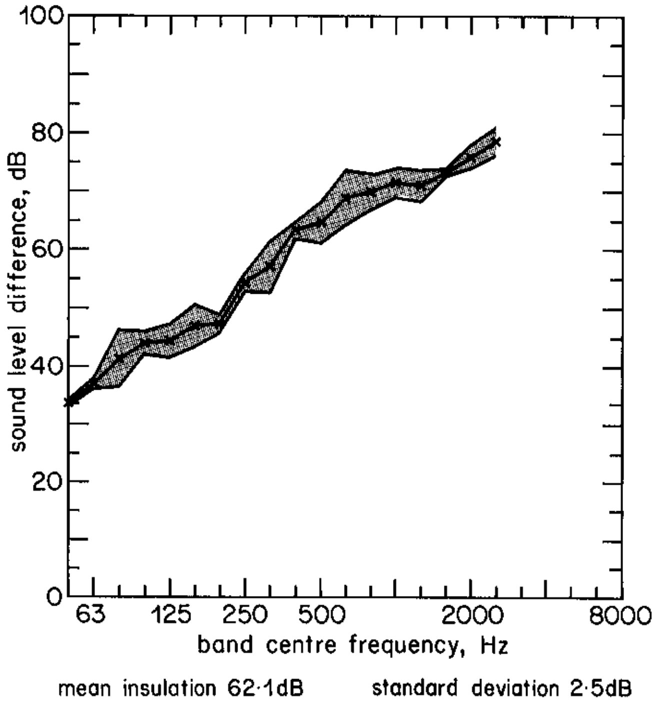


Fig.6 - Sound insulation of triple 150 mm masonry partitions (with triple glazed windows and doors via a lobby).

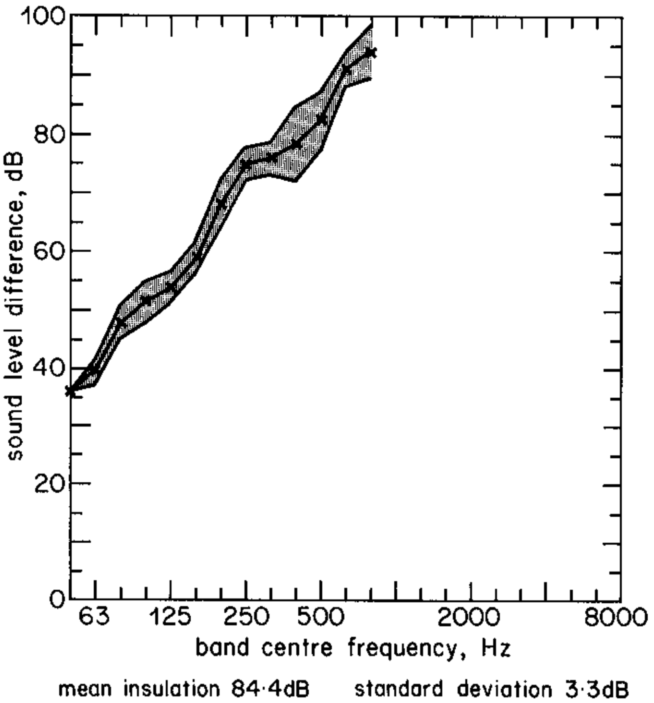


Fig.7 - Sound insulation of triple 150 mm masonry partitions (with no doors or windows).

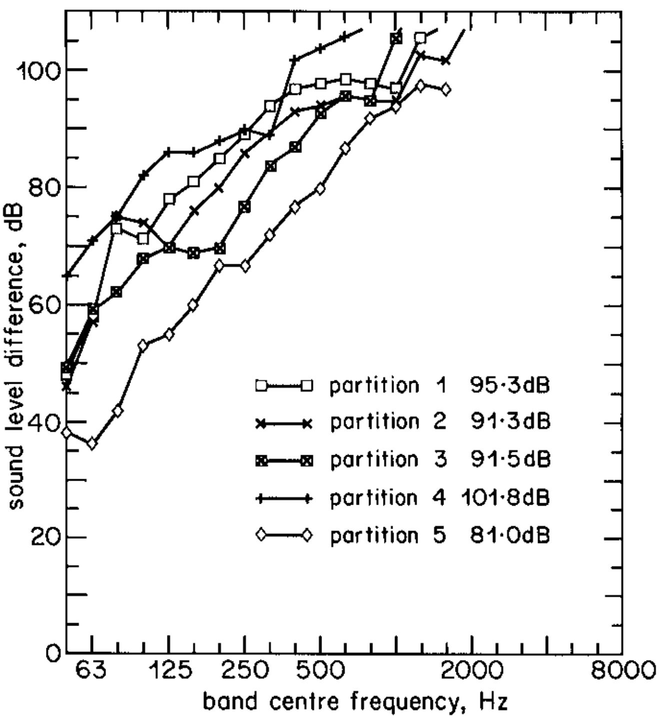


Fig.8 - Partitions with sound insulation greater than 80 dB - Individual results.

Partition 2 consists of one floated box and one non-floated box, with a spine wall between. The floated box comprises a 288 mm brick wall on neoprene pads, separated from the spine wall of 456 mm brick by a 1460 mm cavity. Although the wall of the non-floated box is made of twin 114 mm brick leaves with a 50 mm cavity, it is pierced by a large lead-loaded access door which is obviously the limiting factor in its acoustic performance. The overall partition gives an average sound level difference of 91.3 dB.

Partitions 3 and 4 are between a drama studio and an adjacent pop music control room and pop music studio respectively. Great care was therefore needed in their construction to keep the pop music out of the drama studio. To this end the pop studio was constructed on neoprene pads, the pop control room was not floated, the drama studio was constructed on helical spring antivibration mountings (AVMs) and separate foundations were used, see Fig. 9. For Partition 3, Fig. 9(a), the wall structure was 228 mm brick on spring AVMs, 228 mm cavity, 325 mm brick, 228 mm cavity, 228 mm brick, 125 mm cavity and 228 mm brick. For Partition 4, Fig. 9(b) the structure was 228 mm brick on spring AVMs, 325 mm brick, 325 mm brick and 325 mm brick on neoprene pads, with all cavities at 225 mm. The acoustic performance of Partition 3 was 91.5 dB, whilst the additional vibration break (the pop studio neoprene pads) and heavier walls gave Partition 4 a performance of 101.8 dB.

Finally Partition 5 is a simple (relatively) triple leaf partition. Each leaf is 112 mm brick and the two cavities are 50 mm wide. In this case there are no windows or doors piercing the partition. The average performance for Partition 5 is 81.0 dB.

4.5 Outside Broadcast Vehicle Walls

One of the more difficult types of area to protect from the ingress of noise is the mobile control room. The BBC's fleet of control vehicles is perhaps the largest in the world and it has long been held that the studio managers and operators in such vehicles should, if possible, have the facilities to allow them to make as professional a programme as can be made from a fixed installation. Technical facilities can in general be adapted to the mobile control room but acoustic problems are not so amenable. Not only are the dimensions of the environment restricted but the vehicle has an overall weight limit which prevents the use of massive constructions.

Several solutions have been investigated over the years and the type of construction shown in Fig. 10 is the most common for mobile control rooms. The outer face is 16-gauge aluminium, the middle 'skin' is sound barrier mat (a heavy flexible sheet of mineral loaded plastic material on a fabric backing), whilst the inner face is again aluminium. In between these skins, both for thermal and acoustic reasons, are layers of mineral wool and/or foamed plastic. The inner skin is sometimes perforated to let the foam act as an absorber or sometimes unperforated and covered with carpet. Another option is to stick the sound barrier mat to the outer face. None of these variations has been found to be significant in terms of sound transmission.

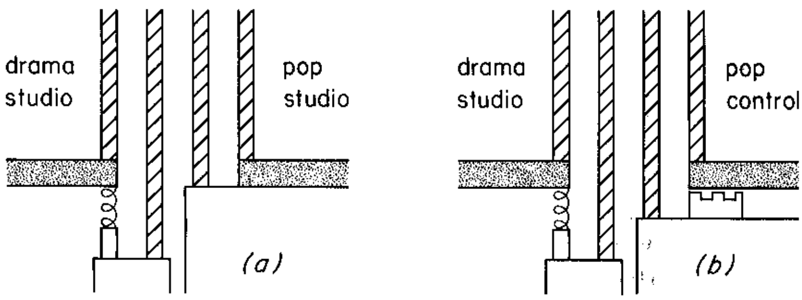


Fig.9 - Examples of constructions used for high sound insulation.

(a) Drama studio to pop control room (91.5 dB)
(b) Drama studio to pop studio (101.8 dB)

Twenty three partitions of this sort have been tested and the average performance is shown in Fig. 11. The curve shows an average fundamental resonance frequency of 80 Hz for this type of partition, giving a minimum insulation of about 15 dB. From there the insulation curve rises progressively to 48 dB at 8 kHz.

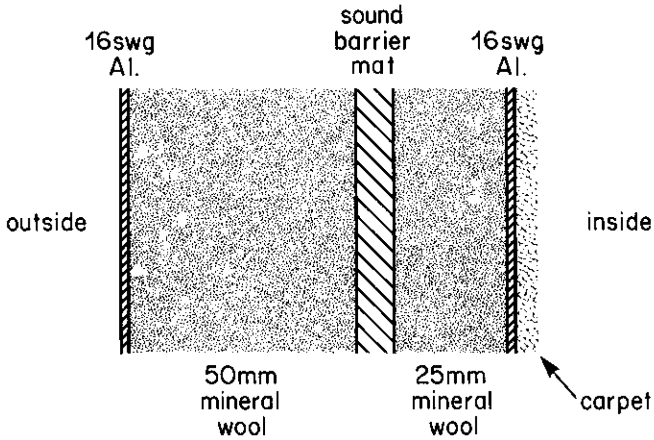


Fig. 10 - Example of the construction of an outside broadcast vehicle wall.

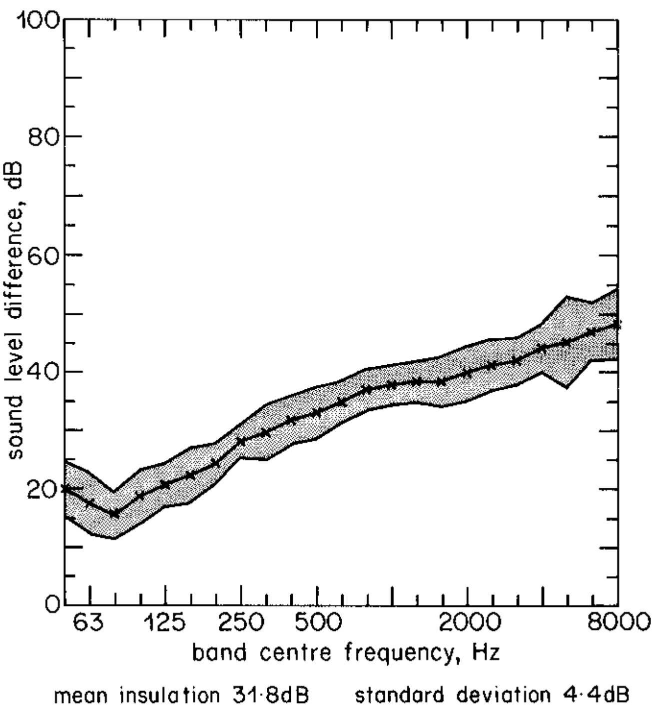


Fig. 11 - Sound insulation of outside broadcast vehicle walls (complex partitions with doors and windows).

What are significant in these designs are the doors and equipment access hatches that have to be included. Great care is given to the detailed design of compression and magnetic seals for these openings but inevitably they are the weak points in the overall partition design. It is only by attention to such details that even reasonable performance can be achieved.

By removing the doors and hatches, the mean performance can be increased from 31.8 dB to 36.9 dB for the same wall construction. By changing the wall construction to plywood instead of aluminium, the average insulation can be further increased to 40.0 dB.

However, the latter improvement is at the expense of increased weight and has only been possible in the BBC for some of its radio vehicles where a lower percentage of the overall vehicle weight is required for technical equipment.

5. CONCLUSIONS

A survey has been carried out on the recorded sound insulation field measurements that have been carried out by the BBC in the last fifteen years.

The results, in the form of sound level difference versus frequency curves, are a useful fund of information for the acoustic design engineer. They range from the fairly modest 32 dB average for Outside Broadcast vehicles to a remarkable 102 dB average for one quadruple brick wall construction incorporating anti-vibration mounts.

This Report has presented an overview of the survey results together with some of the background information which qualifies those results. The full survey data are given in a companion document[1].

Whilst this Report and the companion document will form useful reference documents as they stand, it is intended that the computer data files be kept up to date. Thus any reprint of the database will automatically include the new data and, if appropriate, details of new forms of construction.

6. ACKNOWLEDGEMENTS

The author is grateful to the many people involved over the years in carrying out the sound insulation measurements. He is also particularly grateful to K.E. Randall, of BBC Research Department, and to K.A. Rose, Acoustics Architect in the BBC Architectural and Civil Engineering Department, for careful checking of the data and for supplying much of the information on building structures.

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